

# Comment on "Theory of tailoring sonic devices: Diffraction dominates over refraction"

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Recently N. García *et al.* (Phys. Rev. E **67**, 046606 (2003)) theoretically studied several acoustic devices with dimensions on the order of several wavelengths. The authors discussed experimental results previously reported by several of us (F. Cervera *et al.*, Phys. Rev. Lett. **88**, 023902 (2002)). They concluded that it is diffraction rather than refraction that is the dominating mechanism explaining the focusing effects observed in those experiments. In this Comment we reexamined their calculations and discussed why some of their interpretations of our results are misleading.

The recent paper by Garcia *et al.* [1] addressed an issue of interest in the field of acoustic crystals (ACs). It concerns the role that diffraction plays vs. refraction in determining the effects observed in acoustic devices with dimensions of the order of several wavelengths. In our opinion, this issue is related with the problem of homogenization of clusters consisting of periodic arrangements of sonic scatterers in air. In other words, if the AC-based device is large enough so that its properties can be explained in terms of an effective medium theory (where a refractive index can be defined), one would say that refraction dominates over diffraction. The existence of a critical size above one can consider that refraction dominates over diffraction is an issue that was not taken into account in the paper by Garcia *et al.* [1].

In regards with the acoustic devices presented in Ref.[1], we agree to the general conclusion obtained by the authors from their theoretical simulations; i.e., focusing phenomena and image formation are dominated by diffraction rather than refraction due to the small dimension of the acoustic devices studied. Nevertheless, the authors in Ref. [1] criticize the results recently reported by several of us for much larger structures, for which we claimed that refraction is a dominant mechanism.[2]. This Comment is to clarify on some misconceptions and criticisms made by the authors of Ref. [1]. We also have reexamined their predictions and new experiments will be presented that confirm our own simulations based on multiple scattering theory (MST).

In order to reproduce experimental findings, Garcia *et al.* [1] used acoustical devices like those reported in [2] but with much smaller sizes. As a first case, they employed a FDTD method to simulate the sound scattering by a biconvex cylindrical lens made of only 32 aluminum rods, which they claim "is similar to that of experiment in Ref. [6]" (Ref.[1] in this Comment). In this regard, we have to comment that the actual size of the crystal lens employed in our experiment is about 6 times big-

ger, which has a crucial difference when an analysis of refraction vs. diffraction is made. Figure 1(a) shows the comparison between both structures. As a second case, Ref. [1] presented the simulation of the sound scattering by a slab consisting of only 28 rods to support that focusing effects is dominated by diffraction. At this point, we have to remark that the actual slab employed in our experiments consists of 400 aluminum rods (see Fig. 4 in Ref. [2]). A comparison between both slabs is shown in Fig. 1(b). Obviously, these big differences between the structures theoretically modeled and the ones experimentally employed, made completely misleading the comparison between theory and measurements. Therefore, the smaller size of the structures does not support the argumentation made by Garcia *et al.* In our opinion, the pressure maps shown in Fig. 4 of Ref. [2] clearly demonstrated our conclusion that our lens is dominated by refraction rather than diffraction. Diffraction effects, although present at the edge zones, are completely negligible. On this concern, a theoretical discussion about acoustic lens have been recently reported by Gupta and Ye [3], who used MST to perfectly reproduce our measurements. A further support of the fact that refraction and not diffraction is the dominating mechanism in clusters of comparable size has been recently presented by some of us in Ref. [4], which demonstrated the homogenization of crystal slabs with dimensions similar to the ones used in Ref. [2].

If the acoustic device has a number of scatterers as low as those modeled by García *et al.*, we completely agree that diffraction is the dominant mechanism. To support this conclusion, we made our own theoretical simulations by means of MST as well as measurements on the same structures studied in Ref. [1]. Figures 2(a) and 2(b) show that our theoretical simulations are in agreement with the measurements. At this point, let us remark that our simulations slightly differs with the ones presented in Figs. 2(a) and 2(b) of Ref. [1]. One can observe that

the focal point is located at the same distance in the two structures, which contradict the comment made by García *et al.*. The differences are probably due to the intrinsic limitations of the FDTD method, which does not treat exactly the scattering by a cylindrical rod as the MST does.

To conclude, an important issue is still unsolved: it concerns with the problem of homogenization of acoustic crystals having small dimensions in order to determine the minimum size of cluster at which its properties can be described by effective values of its acoustical parameters.

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FIG. 1: (a) The circles (black and white) define the total set of aluminum cylinders reported as an acoustic lens in Ref. [2]. The partial set defined by the black circles corresponds to the structure employed in the simulation of an acoustic lens in Ref. [1]. (b) The circles (black and white) circles define the set of aluminum cylinders reported as an acoustic Fabry-Perot interferometer in Ref. [2]. The partial set defined by the black circles corresponds to the structure employed in the simulations reported in Ref. [1]. The separation between ticks in both figures corresponds to one wavelength.

FIG. 2: (a) (top panel) Calculated pressure pattern (in dB) of an incident sound plane wave (1700 Hz wavelength) scattered by a lenslike periodic arrangements of rigid rods (white circles) with hexagonal symmetry. (a) (bottom panel) Measured pressure pattern of the corresponding structure made of aluminum cylinders. (b) (top panel) Calculated pressure pattern (in dB) of an incident sound plane wave (1700 Hz wavelength) scattered by a rectangular slab of rigid rods (white circles). (a) (bottom panel) Measured pressure pattern of the corresponding structure made of aluminum rods. Details of calculation's method and measurements can be found in Ref. [4].



